

“On the Spontaneous Ionisation of Gases.” By C. T. R. WILSON,
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Received October 22,—Read December 5, 1901.

It was shown by Geitel,* and independently by the writer of this paper,† that there is a continuous production of ions in air contained in a closed vessel, even when it is not exposed to any known ionising agent. The present communication contains the results of measurements of the relative rates of production of ions under such conditions in air and certain other gases.

The relative ionisations (the term “ionisation” being used in the sense of “rate of production of ions”) were obtained by a comparison of the “saturation” currents in the various gases. The apparatus used for this purpose differed only in minor details from that described and figured in a previous paper.‡

The vessel in which the ionisation was measured was a glass bulb 5·5 cm. in diameter, thinly silvered internally. The conducting system, from which took place the loss of charge to be measured, consisted of a brass wire with a narrow strip of gold leaf attached, the wire being fixed by means of a small bead of sulphur to a brass rod passing through a plug of sealing-wax in the neck of the bulb. This supporting rod was kept at a constant potential by means of a condenser, consisting of zinc plates embedded in sulphur. Electrical connection could be made when required between the leaking system and the supporting rod by means of a strip of watch balance-spring, soldered at its upper end to the supporting rod, and with its lower end bent so as to form a bridge over the sulphur bead. By approaching a magnet to the neck of the bulb the free end of the spring could be brought into contact with the upper end of the brass wire carrying the gold leaf.

The position of the gold leaf was read by means of a microscope provided with an eye-piece micrometer-scale. On the portion of the scale used, one scale division corresponded to 0·31 volt, as tested by means of a Clark cell. An initial potential of about 90 volts was used in the experiments.

To make a determination of the rate of leak, the brass wire and gold leaf were brought to the potential of the supporting rod by making momentary electrical connection by means of the magnetic contact maker. The time indicated by a watch at the moment of transit of the gold leaf across the next scale division was then observed; the moment of transit across a lower scale division about one hour later was also observed. Contact was then made a second time and the position of the gold leaf again read. The time taken by the gold leaf to traverse a certain whole number of scale divisions was thus deter-

* ‘Physik. Zeitschrift,’ 2 Jahrgang, No. 8, pp. 116–119.

† ‘Camb. Phil. Soc. Proc.’ vol. 11, p. 32; ‘Roy. Soc. Proc.’ vol. 68, pp. 151–161.

‡ ‘Roy. Soc. Proc.’ vol. 68, p. 155.



mined, and the constancy of the potential of the supporting rod at the same time tested.

The number of scale divisions traversed during the course of a determination of the leak did not in any case exceed ten ; in the case of the smallest rates of leak measured only one scale division was traversed. As one scale division corresponded to 0·31 volt, the potential of the leaking system never fell more than about 3 volts below that of the supporting rod.

The potential of the supporting rod did not itself remain absolutely constant, but fell generally from 1 to 2 volts in the hour, unless a small additional charge was given to the condenser during the course of the experiment ; this was done in the case of the smaller leaks. The correction to be applied for a fall of potential of the support corresponding to a given number of scale divisions was determined by first making contact by means of the magnet, then reducing the potential of the supporting rod sufficiently to move the gold leaf across a whole number of scale divisions, and again making contact and observing the new potential of the supporting rod. It was found that to make a change of potential in the leaking system corresponding to one scale division (the charge remaining constant) a change of potential of the supporting rod corresponding to 5·4 divisions was required ; or the correction to be applied for a fall of potential of the supporting rod corresponding to one scale division amounted to 0·18 of a division.

The error due to want of perfect insulating power in the sulphur bead was certainly very small. Even when the supporting rod was earthed, so that the difference of potential between the two conducting systems separated by the sulphur was about 90 volts, the movement of the gold leaf, when the apparatus was exhausted, did not exceed one division per hour. Under the conditions of the actual experiment the difference of potential between the two systems never exceeded 3 volts, and with the apparatus exhausted no leak was observed.

The apparatus for the preparation and drying of the gases was sealed on to the bulb in which the leakage was measured, all joints being made with the blow-pipe. A mercury pump served to exhaust the apparatus before the introduction of the gases. The gases were dried by passing them slowly over phosphoric anhydride.

The air was admitted through a cotton-wool filter. The carbonic acid was prepared by heating sodium bicarbonate. The hydrogen used in the first experiments was prepared from zinc and sulphuric acid ; in the later experiments the gas thus obtained was absorbed by palladium, from which it was set free by heating. The sulphur dioxide was obtained from a "siphon" of the liquid substance. The chloroform vapour was obtained from the commercial substance. The temperature ranged from 20° to 24° C. The results are given in the tables which follow.

Air.

	Pressure in centimetres of mercury.	Leak, scale divisions per hour (corrected).	Leak/pressure.
(1)	76	8·0	0·105
(2)	68	7·3	0·107
(3)	57	6·3	0·111
(4)	51	5·3	0·104
(5)	40	4·9	0·122
(6)	27	3·45	0·128
(7)	16	2·0	0·125
(8)	10	1·2	0·12

Leak/pressure, mean of (5) (6) (7) = 0·125.

Hydrogen.

	Pressure in centimetres of mercury.	Leak, scale divisions per hour (corrected).	Leak/pressure.
(1)	77	1·75	From Zn and H ₂ SO ₄ .
(2)	77	1·70	" "
(3)	77	1·67	palladium.
(4)	77	1·94	" "
(5)	70	1·6	0·023
(6)	68	1·5	0·022 From Zn and H ₂ SO ₄ .
(7)	43	0·96	0·022 " palladium.
(8)	36	0·7	0·020 " "

Leak/pressure, mean of (1)–(7) = 0·0225.

Relative leak (air = 1)..... = 0·184.

Carbonic Acid.

	Pressure in centimetres of mercury.	Leak, scale divisions per hour (corrected).	Leak/pressure.
(1)	49	8·7	0·178
(2)	41	7·7	0·188
(3)	35	7·1	0·203
(4)	28	6·1	0·218
(5)	23	4·8	0·209
(6)	17	3·3	0·194
(7)	9·7	1·9	0·196
(8)	4·6	1·1	0·24

Leak/pressure, mean of (3)–(6) = 0·211.

Relative leak (air = 1)..... = 1·69.

Sulphur Dioxide.

	Pressure in centimetres of mercury.	Leak, scale divisions per hour (corrected).	Leak/pressure.
(1)	21.3	5.3	
(2)	21.3	5.7	
(3)	12.3	3.9	
(4)	12.3	3.9	
(5)	12.3	4.25	
(6)	7.3	2.3	
(7)	7.3	2.5	
(8)	7.3	2.4	

Leak/pressure, mean of (3)-(8) = 0.33.

Relative leak (air = 1) = 2.64.

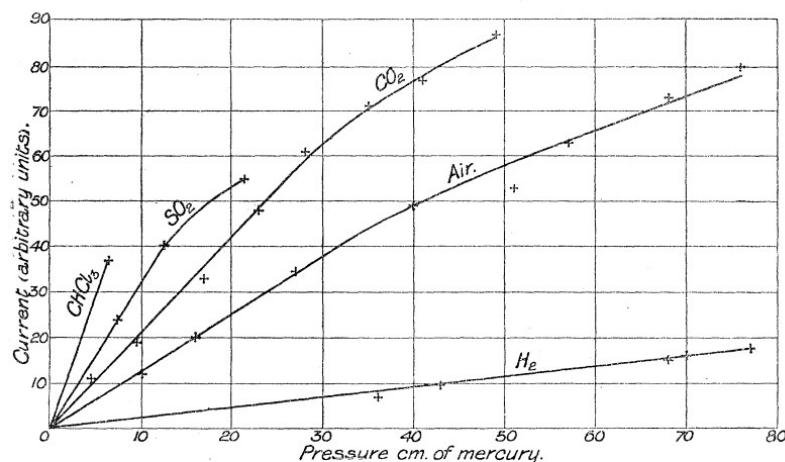
Chloroform.

	Pressure in centimetres of mercury.	Leak, scale divisions per hour (corrected).	Leak/pressure.
(1)	6.3	3.6	
(2)	6.3	3.8	

Leak/pressure, mean = 0.59.

Relative leak (air = 1) = 4.7.

These results are represented graphically below.



It will be noticed that except at the higher pressures the leak is proportional to the pressure. The falling off from this law at the higher pressures might be taken as indicating that the ionisation is due to radiation from the walls of only moderate penetrating power; it is possible, however, that at the higher pressures a sensible proportion of the ions recombine, so that the current is not a measure of the ionisation. There can be no doubt that, for the range of pressures for which the leakage is proportional to the pressure, we may consider that the saturation current was attained, and the rate of leak may be taken as a measure of the ionisation. It is for such pressures that the relative ionisations have been calculated. They are collected together in the table which follows.

Gas.	Relative ionisation.	Relative ionisation. Specific gravity.
Air	1.00	1.00
H ₂	0.184	2.7
CO ₂	1.69	1.10
SO ₂	2.64	1.21
CHCl ₃	4.7	1.09

If we except hydrogen, the ionisation is seen to be very nearly proportional to the density of the gas. The deviations in the case of the other gases in fact hardly exceed what might be attributed to experimental errors, for variations amounting to as much as 10 per cent. occurred in the determination of the rate of leak for a given gas. The departure from the law in the case of hydrogen cannot be attributed to experimental error, nor is it due to want of purity of the gas, as is shown by the agreement in the results obtained with the gas prepared by different methods.

The results obtained for the relative ionisation occurring spontaneously in all the gases tried, including hydrogen, show a remarkable similarity to those obtained by Strutt* in the case of the same gases when under the action of the Becquerel rays, as the following table shows (p. 282).

It was pointed out by Strutt that the conductivity under the action of the rays is nearly proportional to the density of the gas, hydrogen, however, being an exception. As will be seen, the results I have obtained for the spontaneous ionisation agree more nearly with those obtained by Strutt for gases exposed to radium radiation than for the same gases under the action of polonium rays.

An account of measurements of the loss of electricity from a charged conductor suspended in a closed vessel containing various

* 'Phil. Trans.,' A, vol. 196, pp. 507-527.

gases was published by Matteucci* in 1850. He found the loss to be the same in air, carbonic acid, and hydrogen. Warburg,† in 1872, found the loss in air and carbonic acid to be equal, and in hydrogen about half as great. They used much larger vessels, and it is probable that in Warburg's experiments the saturation current was not approached, so that the leakage was not even approximately proportional to the ionisation; it is perhaps in this way that the discrepancy is to be explained.

Relative Conductivity (Air = 1).

Gas.	Radium rays (penetrating type).	Polonium rays.	Spontaneous ionisation.
Air	1·00	1·00	1·00
Hydrogen	0·157	0·226	0·184
Carbonic acid.....	1·57	1·54	1·69
Sulphur dioxide	2·32	2·04	2·64
Chloroform	4·89	4·44	4·7

In Matteucci's experiments, however, the leakage was independent of the potential; he was therefore using potentials high enough to produce the saturation current, and some other explanation is in this case required. One possible way out of the difficulty would be to suppose that the ionisation is to be explained by a slight radio-activity of the walls, the radiation being of only moderate penetrating power. In a large vessel all the radiation might be absorbed even by hydrogen, and in that case we should expect to find the same total number of ions produced in a given time whatever gas the vessel contained.‡ At the same time the similarity between the results obtained for the relative ionisations of different gases in the small vessel with those of the same gases exposed to the action of radium would be explained (the ionisation being due to a similar cause), as also would the departure at the higher pressures from the simple law connecting pressure and rate of leak, which holds for the lower pressures, for at the higher pressures the intensity of the rays might be considerably reduced by absorption before reaching the central portions of the vessel.

Until, however, further experiments have been made it would, I think, be premature to conclude that the ionisation is due to radiation from the walls of the vessel.

* 'Annales de Chimie et de Physique,' vol. 28, pp. 385-429.

† 'Annalen d. Physik u. Chemie,' vol. 145, pp. 578-599.

‡ As in gases exposed to uranium rays in a large vessel (Rutherford, 'Phil. Mag.', vol. 47, p. 136, 1899).